Structural Material Laboratory
Engineering Lab Building 113 and 115

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The experimental test results of this study presents the mix design proportions, compressive strength, flexural strengths, permeability, total air voids and petrographic analysis, and freeze and thaw data for treated and untreated specimens. The following tests were conducted to evaluate the durability characteristics of the treated with Chem-Crete Pavix CCC 100 and untreated specimens.

1. Compressive Strength testing (ASTM C 39-01)
2. Flexural Strength testing (ASTM C 78-00)
3. Specific Gravity, Absorption, and Voids in Hardened Concrete (ASTM 642-97)
4. Standard Test method for Determination of Water Absorption of Hardened Concrete Treated With a Water Repelling Coating (ASTM C 6489-99)
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1.1 Mix Proportions

Several possible mix design procedures were studied prior to the selection of a suitable mix design for this research. Since the waterproofing materials used in this research are primarily used in pavement, the mix design selected for this research was selected on the basis of a typical pavement mix design. Each mix design was conducted for expected slump value of 5 inch, air content 5% and water cement ratio of 0.5. The mix proportion for concrete is presented in Table1.

Table 1 Mix Design

INGREDIENTS	lb/yd^3
Water	260
Cement	517
Coarse Aggregate	1850.1
Fine Aggregate	1286.1
Total	3931.1 lb/yd^3

The admixture used was 3.0 FL.Ozs /100 cement weights for water reducing and 0.4 FL.Ozs /100 cement weights for air content.

1.2 Compressive Strength Test

The compressive strength tests specimens consisted of 6 in. diameter cylinders with 12 in. height. Three cylinders were tested at standard 28-day, and their average value was calculated and recorded. The target 28-day compressive strength of the mix design was 3500 psi. The measured compressive strength of the mix was within the range of +/- 10% of the targeted compressive strength.

The 28-day compressive strength test results for the given concrete mix design used in the research are provided in Table 2 and Figure 1. Since concrete used in this research achieved targeted 28-day compressive strength, the concrete was identified as acceptable to be used for further laboratory testing.

Table 2 28-Day Compressive Strength Test

Specimen no.	Diameter (inch)	Area ($inch^2$)	Maximum Load (lbf)	Compressive strength (psi)
C-1	6	28.287	111,100	3930
C-2	6	28.287	107,900	3816
C-3	6	28.287	110,900	3922
Average	6	28.287	109965.67	3890

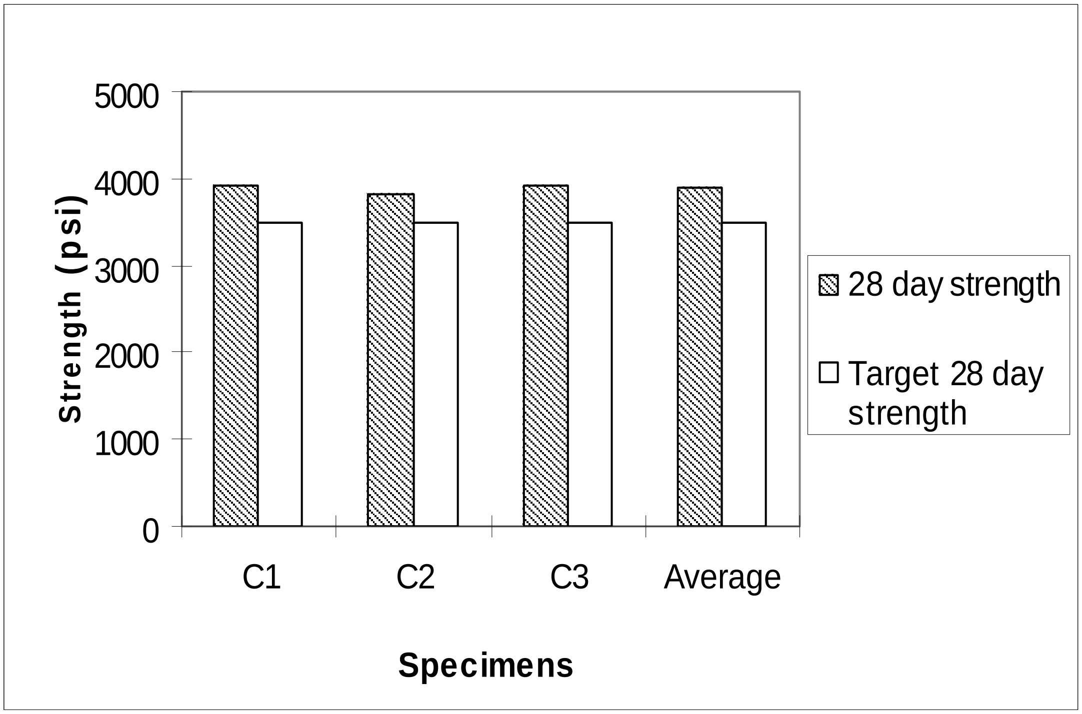

Figure 1 Comparison of Compressive strength

1.3 <u>Flexural Strength Test</u>

The flexural strength test was conducted with 6 in. x 6 in. x 20 in. concrete beam specimens. The third point loading standard test method was conducted to determine the modulus of rupture, which is a measure of flexural strength in concrete. This test was conducted at the same testing periods as compressive strength tests and the three beams specimens were tested at each test period to give an average strength result for each mix design.

The 28-day flexural strength experimental test results for the concrete used in this research are given in Figure 2 and Table 3, which show that all the three specimens tested for 28-day flexural tests, pass the minimum 28-days flexural strength provided by the TXDOT. The average of three specimens is 573 psi which is well above the minimum requirement of 555 psi required by the Texas Department of Transportation (TXDOT).

Table 3 28-Day Flexural Strength Test

Specimen No.	Maximum Applied load (lbf)	L (in.)	Bd^2 (6” x 6”) (in^2)	MOR (psi)
F-1	7000	18.	216	585
F-2	6800	18	216	567
F-3	6800	18	216	567
Average	6867	18	216	573

L = the span length of the bottom supports

B = the average base (or width) at the failure plane

d = the average depth at the failure plane

MOR = Modulus of Rupture

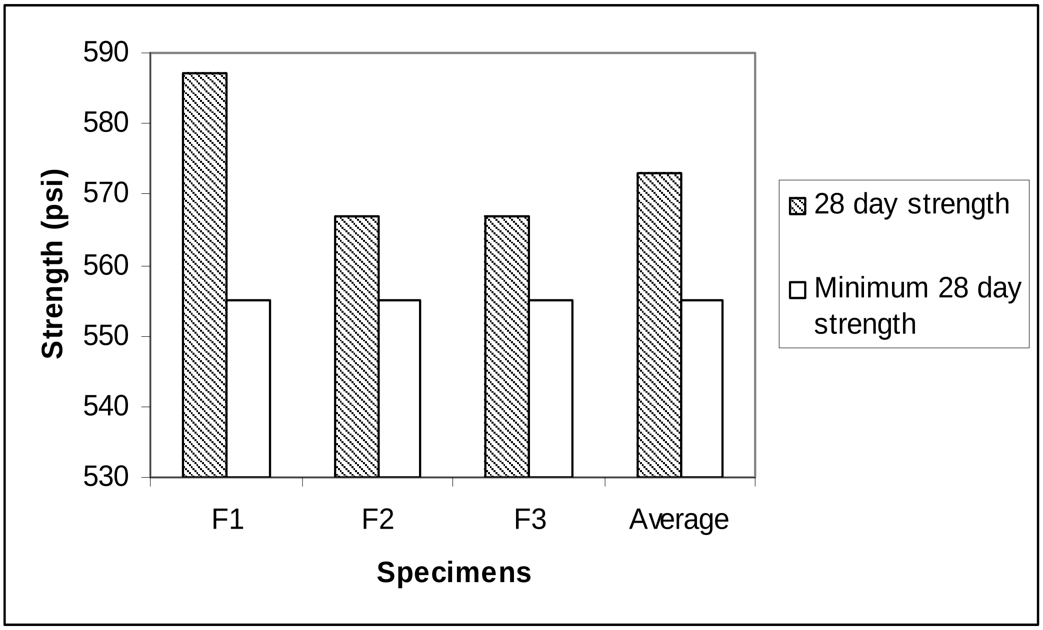

Figure 2 Comparison of Flexural Strength

1.4 Air Void System Test

The test results of this procedure include specific gravity, percent absorption, and percent void in hardened concrete. This result is useful in developing mass/volume conversions for concrete. The test results for percent voids can be useful in understanding the permeability test results. The larger percentages of total voids in hardened concrete will aid increasing of permeability of a concrete specimen.

The test specimens used for this study consisted of six 4 in. x 8 in. cylinder and six 6 in. x 6 in. x 4 in. beam specimens obtained from remain of the flexural test beam (6 in. x 6 in. x 20 in.) specimens. In addition to this, additional test samples for absorption test were prepared with different mix designs. After 28 days of curing period, half of the specimens were treated with waterproofing substance CHEM-

CRETE PAVIX CCC 100 and were cured for additional 7 day before they are ready for the test.

The experimental test results for concrete mix used in this research and additional mix design for absorption test are presented in Tables 4 through 10.

Table 4 Absorption Test Result of Untreated Specimen (w/c ratio 0.35)

	Control 1	Control 2	Control 3	Average
Mass of oven dried sample in air, lb (A)	28.55	28.75	29.35	28.88
Mass of surface dry sample in air after immersion, lb (B)	29.70	29.95	30.45	30.03
*Absorption after immersion, %	4.02	4.17	3.74	3.97

Table 5 Absorption Test Result of Treated Specimen (w/c ratio 0.35)

	Treated 1	Treated 2	Treated 3	Average
Mass of oven dried sample in air before coating, lb (WA)	29.60	29.55	29.55	29.56
Mass of surface dry sample in air after coating, lb (W1)	29.70	29.60	29.60	29.63
Mass of surface dry sample in air after immersion, lb (W2)	29.95	29.90	29.85	29.9
*Absorption after immersion, %	0.84	1.01	0.84	0.89

Table 6 Absorption Test Result of Untreated Cylinder (w/c ratio 0.5)

	AT-UTC-1	AT-UTC-2	AT-UTC-3
Mass of oven dried sample in air, lb (A)	7.40	7.45	7.40
Mass of surface dry sample in air after immersion, lb (B)	7.85	7.90	7.90
*Absorption after immersion, %	6.08	6.04	6.75

The average water absorption rate of untreated cylinder specimens is 6.29 %.

Table 7 Absorption Test Result of Untreated Beam (w/c ratio 0. 5)

	AT-UTB-1	AT-UTB-2	AT-UTB-3
Mass of oven dried sample in air, lb (A)	11.00	10.75	10.85
Mass of surface dry sample in air after immersion, lb (B)	11.65	11.35	11.50
*Absorption after immersion, %	5.90	5.58	5.99

The average water absorption rate of untreated cylinder specimens is 5.82 %.

Table 8 Absorption Test Result of Treated Cylinder (w/c ratio 0.5)

	AT-TC-1	AT-TC- 2	AT-TC-3
Mass of oven dried sample in air before coating, lb (W_A)	7.40	7.50	7.45
Mass of surface dry sample in air after coating, lb (W_1)	7.55	7.65	7.60
Mass of surface dry sample in air after immersion, lb (W_2)	7.75	7.85	7.80
*Absorption after immersion, %	2.70	2.67	2.68

The average water absorption rate of treated cylinder specimens is 2.68 %.

Table 9 Absorption Test Result of Treated Sample (w/c ratio 0.5)

	AT-TB-1	AT-TB-2	AT-TB-3
Mass of oven dried sample in air before coating, lb (W_A)	11.10	11.10	10.95
Mass of surface dry sample in air after coating, lb (W_1)	11.30	11.35	11.15
Mass of surface dry sample in air after immersion, lb (W_2)	11.45	11.50	11.35
*Absorption after immersion, %	1.35	1.35	1.82

The average water absorption rate of Treated Beam specimens is 1.50 %.

Table 10 Complete Air void Test Result (w/c ratio 0.5)

		A	B	C	D	AI	AIMb	BD	BDI	BDIB	AD	VPPS
utb1		11.00	11.65	11.75	6.50	5.91	6.82	2.10	2.24	2.24	2.44	14.29
utb2		10.75	11.35	11.45	6.40	5.58	6.51	2.13	2.27	2.27	2.47	13.86
utb3		10.85	11.50	11.65	6.40	5.99	7.37	2.07	2.22	2.22	2.44	15.24
					average	5.83	6.90	2.10	2.24	2.24	2.45	14.46
utc1		7.40	7.85	7.90	4.40	6.08	6.76	2.11	2.26	2.26	2.47	14.29
utc2		7.45	7.90	7.95	4.45	6.04	6.71	2.13	2.27	2.27	2.48	14.29
utc3		7.40	7.90	7.95	4.40	6.76	7.43	2.08	2.24	2.24	2.47	15.49
					average	6.29	6.97	2.11	2.26	2.26	2.47	14.69
	Wa											
tb1	11.10	11.30	11.45	11.55	6.60	1.35	2.21	2.28	2.33	2.33	2.40	5.05
tb2	11.10	11.35	11.50	11.65	6.50	1.35	2.64	2.20	2.26	2.26	2.34	5.82
tb3	10.95	11.15	11.35	11.45	6.55	1.83	2.69	2.28	2.34	2.34	2.42	6.12
					average	1.51	2.52	2.25	2.31	2.31	2.39	5.66
tb1	7.40	7.55	7.75	7.85	4.45	2.7	3.97	2.22	2.31	2.31	2.44	8.82
tb2	7.45	7.65	7.85	7.90	4.50	2.68	3.27	2.25	2.32	2.32	2.43	7.35
tb3	7.45	7.60	7.80	7.90	4.50	2.68	3.95	2.24	2.32	2.32	2.45	8.82
					average	2.69	3.73	2.24	2.32	2.32	2.44	8.33

Wa= mass of oven dry sample for treated sample.
A= mass of oven dry sample for untreated sample, dry mass of treated sample after coating.
B= saturated mass of sample after immersion
C= saturated wt of a sample after boiling
D= Immersed apparent mass
AI = Absorption after immersion (%)
AIMb= Absorption after immersion and boiling (%)
BD= Bulk density, dry
BDI= Bulk density after immersion
BDIB= bulk density after immersion and boiling
AD= Apparent Density
VPPS= Volume of permeable pore space (%)

The test results presented in above tables show that by the application of waterproofing material Chem-Crete Pavix CCC 100 , the absorption capacity of concrete was significantly reduced by more than 50%. The volume of permeable pore space (percent voids) is also reduced with the application of Chem-Crete Pavix CCC 100 . The comparison of the test result of treated and untreated specimens are presented in Figures 3, 4, and 5, respectively.

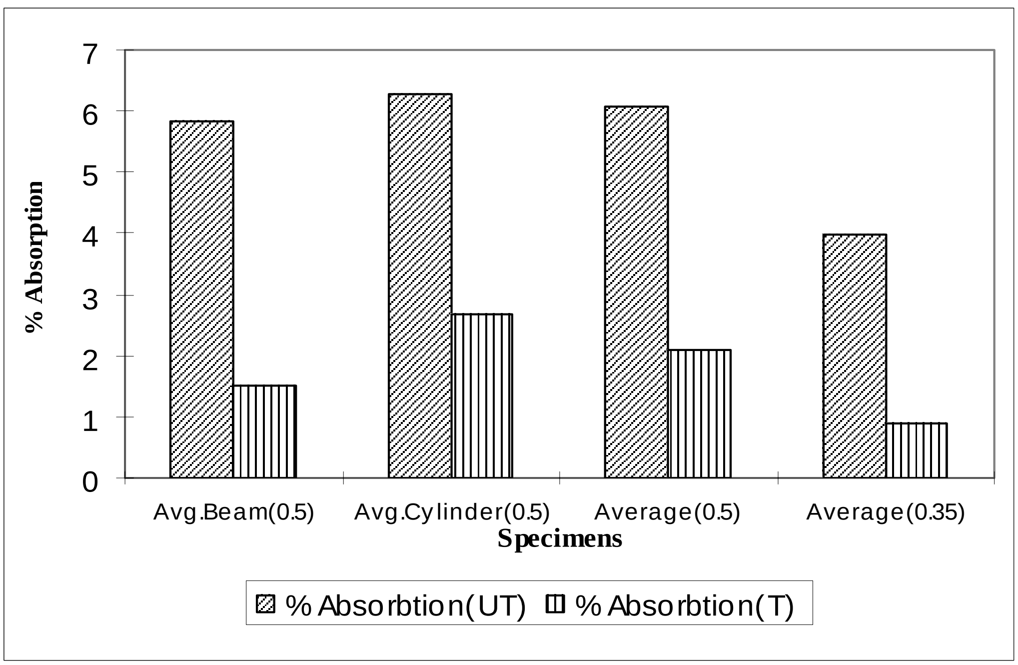

Figure 3 Absorption Test Result

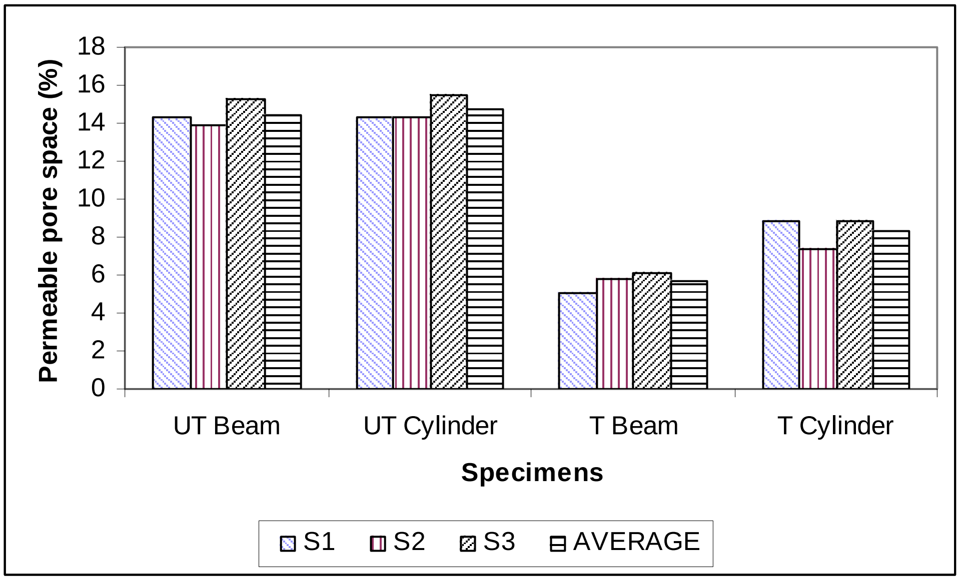

Figure 4 Volume of Permeable Pore Space Test Result

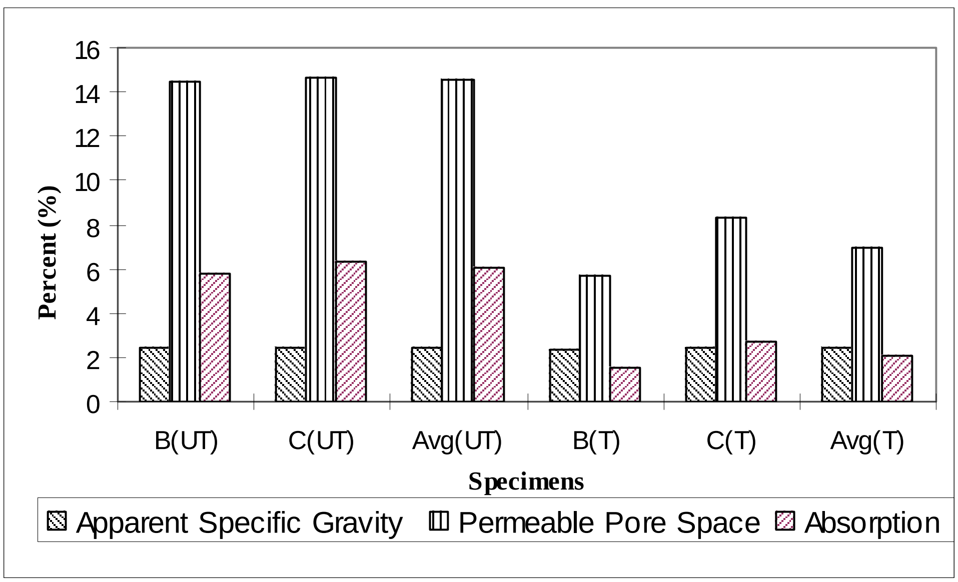

Figure 5 Air-Void System Test Result

Figure 3 shows the comparison of absorption rate between the treated and untreated specimens and mixes. It can be seen that the treated specimens have lower absorption characteristics as compared to that of untreated specimens. It was noticed that the absorption rate is reduced by more than 50% in both cases. From Figure 4, we can see that volume of permeable pore space is reduced by the application of waterproofing substance. This shows that untreated specimens are more permeable than treated specimens, which is due to unique properties of waterproofing material Chem-Crete Pavix CCC 100 that combines the repelling function along with a hygroscopic and hydrophilic moisture blocking mechanism.

1.5 Freeze and Thaw Test

Freeze-Thaw Test was performed in Material laboratory in University of Texas at Arlington (UTA). The equipment used to perform this test procedure consists of automatic Freeze and Thaw apparatus and a length change comparator. For this test we performed the optional length change test. There were 300 freeze-thaw cycles performed for all the specimens. Measurement including length and weight were obtained for approximately every 50 cycles.

For a design mix, eight 4 in. x 3 in. x 11¼ in. specimens, with embedded gauge studs at each end were cast in the laboratory in accordance with ASTM C 192. It is not recommended that freeze-thaw testing be continued on specimens after there is 0.10% expansion or change in length.

The test results of treated and untreated specimens for freeze and thaw test are presented in Tables 11 through 16.

Table 11 Freeze and Thaw Test (change in length)

Specimen no	Length of specimen 0 cycle	Length of specimen 33 cycle	Length of specimen 80 cycle	Length of specimen 122 cycle	Length of specimen 172 cycle	Length of specimen 228 cycle	Length of specimen 283 cycle	Length of specimen 304 cycle
UT1	0.1885	0.1894	0.1865	0.1827	0.1815	0.1809	0.1800	0.1797
UT2	0.1385	0.1363	0.1342	0.1332	0.1320	0.1308	0.1298	0.1294
UT3	0.0998	0.0964	0.0946	0.0929	0.0920	0.0908	0.0897	0.0895
UT4	0.1290	0.1299	0.1289	0.1252	0.1234	0.1220	0.1214	0.1212
T1	0.0458	0.0457	0.0448	0.0441	0.0439	0.0431	0.0429	0.0429
T2	0.1385	0.1374	0.1370	0.1364	0.1357	0.1355	0.1354	0.1350
T3	0.0650	0.0635	0.0627	0.0621	0.0615	0.0611	0.0609	0.0608
T4	0.1860	0.1840	0.1836	0.1830	0.1821	0.1817	0.1812	0.1810

Table 12 Freeze and Thaw Test (change in weight)

Specimen no	Weight of specimen 0 cycle	Weight of specimen 33 cycle	Weight of specimen 80 cycle	Weight of specimen 122 cycle	Weight of specimen 172 cycle	Weight of specimen 228 cycle	Weight of specimen 283 cycle	Weight of specimen 304 cycle
UT1	8.30	8.30	8.30	8.30	8.30	8.25	8.25	8.25
UT2	8.40	8.40	8.40	8.40	8.35	8.30	8.30	8.30
UT3	8.35	8.35	8.35	8.30	8.30	8.30	8.25	8.25
UT4	8.35	8.35	8.35	8.35	8.35	8.35	8.30	8.30
T1	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25
T2	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25
T3	8.25	8.25	8.25	8.25	8.25	8.25	8.25	8.25
T4	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30

Table 13 Freeze and Thaw Test (percentage change in length)

no of cycles	percentage length change(UT)	percentage length change(T)
0	0.00000	0.00000
33	-0.00950	-0.01175
80	-0.02900	-0.01800
122	-0.05450	-0.02425
172	-0.06725	-0.03025
228	-0.07825	-0.03475
283	-0.08725	-0.03725
304	-0.09000	-0.03900

Table 14 Freeze and Thaw Test (percentage change in weight)

no of cycles	percentage weight change(UT)	percentage weight change(T)
0	0.00000	0.00000
33	0.00000	0.00000
80	0.00000	0.00000
122	-0.01515	0.00000
172	-0.30300	0.00000
228	-0.60600	0.00000
283	-0.90600	0.00000
304	-0.90600	0.00000

Table 15 Complete Freeze and Thaw Test Result (percentage change in length)

specimen	length (0 cycles)	length (33cycles)	percentage length change(33cycles)	avg
UT1	0.1885	0.1894	0.0090	-0.0095
UT2	0.1385	0.1363	-0.0220	
UT3	0.0998	0.0964	-0.0340	
UT4	0.1290	0.1299	0.0090	
T1	0.0458	0.0457	-0.0010	-0.01175
T2	0.1385	0.1374	-0.0110	
T3	0.0650	0.0635	-0.0150	
T4	0.1860	0.1840	-0.0200	
specimen	length (0 cycles)	length (80cycles)	percentage length change(80cycles)	avg
UT1	0.1885	0.1865	-0.0200	-0.0290
UT2	0.1385	0.1342	-0.0430	
UT3	0.0998	0.0946	-0.0520	
UT4	0.1290	0.1289	-0.0010	
T1	0.0458	0.0448	-0.0100	-0.0180
T2	0.1385	0.1370	-0.0150	
T3	0.0650	0.0627	-0.0230	
T4	0.1860	0.1836	-0.0240	
specimen	length (0 cycles)	length (122cycles)	percentage length change(122cycles)	avg
UT1	0.1885	0.1827	-0.0580	-0.0545
UT2	0.1385	0.1332	-0.0530	
UT3	0.0998	0.0929	-0.0690	
UT4	0.1290	0.1252	-0.0380	
T1	0.0458	0.0441	-0.0170	-0.02425
T2	0.1385	0.1364	-0.0210	
T3	0.0650	0.0621	-0.0290	
T4	0.1860	0.1830	-0.0300	

Table 15-*continued*

specimen	length (0 cycles)	length (172cycles)	percentage length change(172cycles)	avg
UT1	0.1885	0.1815	-0.070	-0.06725
UT2	0.1385	0.1320	-0.0650	
UT3	0.0998	0.0920	-0.0780	
UT4	0.1290	0.1234	-0.0560	
T1	0.0458	0.0439	-0.0190	-0.03025
T2	0.1385	0.1357	-0.0280	
T3	0.0650	0.0615	-0.0350	
T4	0.1860	0.1821	-0.0390	
specimen	length (0 cycles)	length (228cycles)	percentage length change(228cycles)	avg
UT1	0.1885	0.1809	-0.0760	-0.07825
UT2	0.1385	0.1308	-0.0770	
UT3	0.0998	0.0908	-0.0900	
UT4	0.1290	0.1220	-0.0700	
T1	0.0458	0.0431	-0.0270	-0.03475
T2	0.1385	0.1355	-0.0300	
T3	0.0650	0.0611	-0.0390	
T4	0.1860	0.1817	-0.0430	
specimen	length (0 cycles)	length (283cycles)	percentage length change(283cycles)	avg
UT1	0.1885	0.1800	-0.0850	-0.08725
UT2	0.1385	0.1298	-0.0870	
UT3	0.0998	0.0897	-0.1010	
UT4	0.1290	0.1214	-0.0760	
T1	0.0458	0.0429	-0.0290	-0.03725
T2	0.1385	0.1354	-0.0310	
T3	0.0650	0.0609	-0.0410	
T4	0.1860	0.1812	-0.0480	
specimen	length (0 cycles)	length (304 cycles)	percentage length change(304cycles)	avg
UT1	0.1885	0.1797	-0.0880	-0.0900
UT2	0.1385	0.1294	-0.0910	
UT3	0.0998	0.0895	-0.1030	
UT4	0.1290	0.1212	-0.0780	
				avg
T1	0.0458	0.0429	-0.0290	-0.0390
T2	0.1385	0.1350	-0.0350	
T3	0.0650	0.0608	-0.0420	
T4	0.1860	0.1810	-0.0500	

Table 16 Complete Freeze and Thaw Test Result (percentage change in weight)

specimen	weight (0 cycles)	weight (33cycles)	percentage weight change(33cycles)	avg
UT1	8.30000	8.30000	0.00000	0.00000
UT2	8.40000	8.4000	0.00000	
UT3	8.35000	8.35000	0.00000	
UT4	8.35000	8.35000	0.00000	
T1	8.25000	8.25000	0.00000	0. 00000
T2	8.25000	8.25000	0.00000	
T3	8.25000	8.25000	0.00000	
T4	8.30000	8.30000	0.00000	
specimen	weight (0 cycles)	weight (80cycles)	percentage weight change(80cycles)	avg
UT1	8.30000	8.30000	0.00000	0.00000
UT2	8.40000	8.40000	0.00000	
UT3	8.35000	8.35000	0.00000	
UT4	8.35000	8.35000	0.00000	
T1	8.25000	8.25000	0.00000	0. 00000
T2	8.25000	8.25000	0.00000	
T3	8.25000	8.25000	0.00000	
T4	8.30000	8.30000	0.00000	
specimen	weight (0 cycles)	weight (122cycles)	percentage weight change(122cycles)	avg
UT1	8.30000	8.30000	0. 00000	-0.15060
UT2	8.40000	8.40000	0. 00000	
UT3	8.35000	8.30000	-0.60240	
UT4	8.35000	8.35000	0. 00000	
T1	8.25000	8.25000	0. 00000	0. 00000
T2	8.25000	8.25000	0. 00000	
T3	8.25000	8.25000	0. 00000	
T4	8.30000	8.30000	0. 00000	

Table 16-*continued*

specimen	weight (0 cycles)	weight (172cycles)	percentage weight change(172cycles)	avg
UT1	8.30000	8.30000	0. 00000	-0.30030
UT2	8.40000	8.35000	-0.59880	
UT3	8.35000	8.30000	-0.60240	
UT4	8.35000	8.35000	0. 00000	
T1	8.25000	8.25000	0. 00000	0. 00000
T2	8.25000	8.25000	0. 00000	
T3	8.25000	8.25000	0. 00000	
T4	8.30000	8.30000	0. 00000	
specimen	weight (0 cycles)	weight (228cycles)	percentage weight change(228cycles)	avg
UT1	8.30000	8.25000	-0.60606	-0.60332
UT2	8.40000	8.30000	-1.20481	
UT3	8.35000	8.30000	-0.60240	
UT4	8.35000	8.35000	0. 00000	
T1	8.25000	8.25000	0. 00000	0. 00000
T2	8.25000	8.25000	0. 00000	
T3	8.25000	8.25000	0. 00000	
T4	8.30000	8.30000	0. 00000	
specimen	weight (0 cycles)	weight (283cycles)	percentage weight change(283cycles)	avg
UT1	8.30000	8.25000	-0.60606	-0.90635
UT2	8.40000	8.30000	-1.20481	
UT3	8.35000	8.25000	-1.21212	
UT4	8.35000	8.30000	-0.60240	
T1	8.25000	8.25000	0. 00000	0. 00000
T2	8.25000	8.25000	0. 00000	
T3	8.25000	8.25000	0. 00000	
T4	8.30000	8.30000	0. 00000	
specimen	weight (0 cycles)	weight (304 cycles)	percentage weight change(304cycles)	avg
UT1	8.30000	8.25000	-0.60606	-0.90635
UT2	8.40000	8.30000	-1.20481	
UT3	8.35000	8.25000	-1.21212	
UT4	8.35000	8.30000	-0.60240	
T1	8.25000	8.25000	0.00000	0.00000
T2	8.25000	8.25000	0.00000	
T3	8.25000	8.25000	0.00000	
T4	8.30000	8.30000	0.00000	

The results from above tables show the change of length and weight of concrete for different cycles of freeze and thaw tests. These tables show that the change of length in the treated sample is less than of the untreated sample. There is no change in weight for the treated specimens after 300 cycles, whereas, some change in weight is found in the untreated specimens. The percentage change in length and weight in treated and untreated specimen are presented in Figures 6 and 7, respectively.

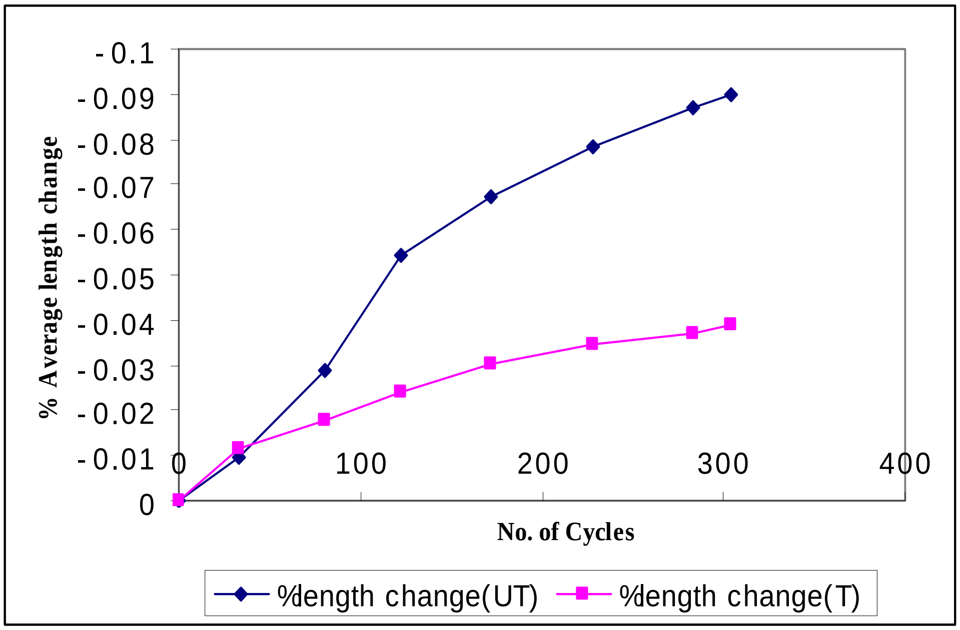

Figure 6 Percentage Length Change of Treated and Untreated Specimens

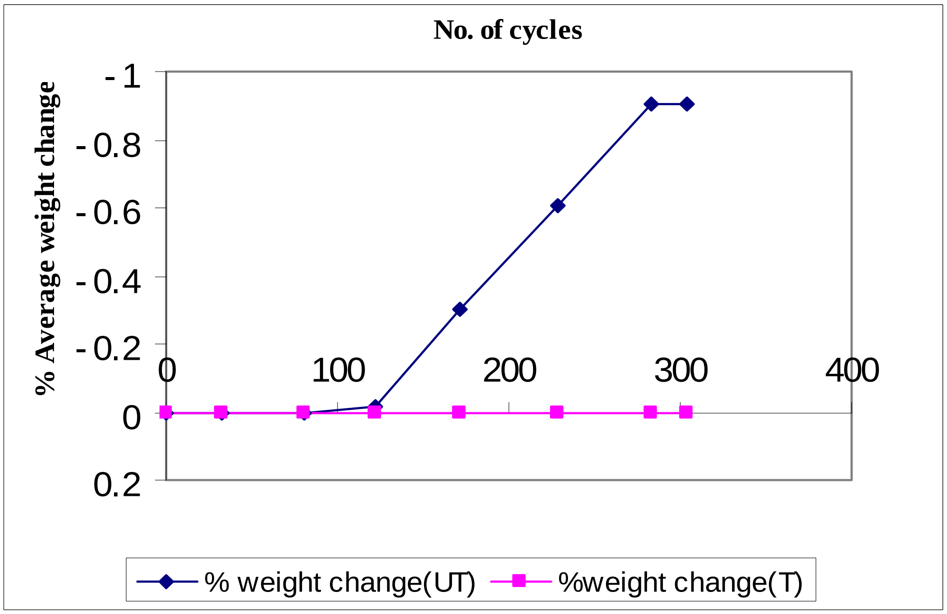

Figure 7 Percentage Weight Change of Treated and Untreated Specimens

From Figure 6, it can be observed that the average percentage length change of the untreated specimen is -0.09% whereas the treated specimen is -0.039. Only one untreated specimen UT-2 changes more than 0.10% after 300 cycles, maximum allowable percentage change in length by ASTM C 666 standard for continuation of test. Figure 7 shows the percentage weight change of treated and untreated specimens. It can be seen that there is no change in weight of the treated specimen, but some change of weight are seen in untreated specimens. The detail graphical representations of percentage length and weight changes for every reading taken are presented in Figures 8 through 14 and Figures 15 through 19, respectively.

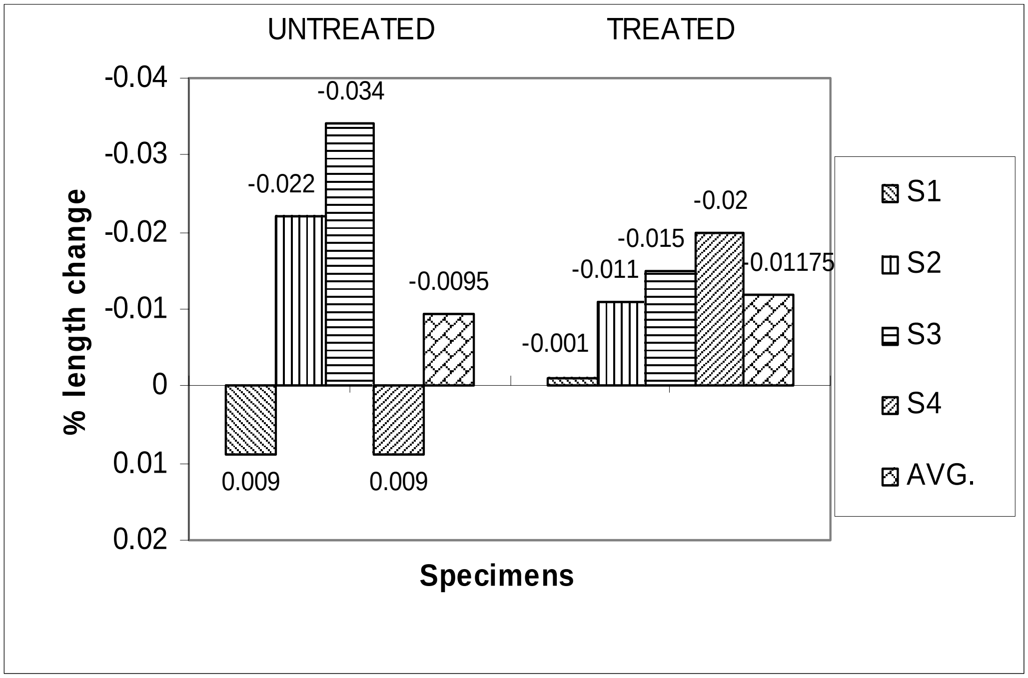

Figure 8 Percentage Length Change of Specimens for 33 Cycles

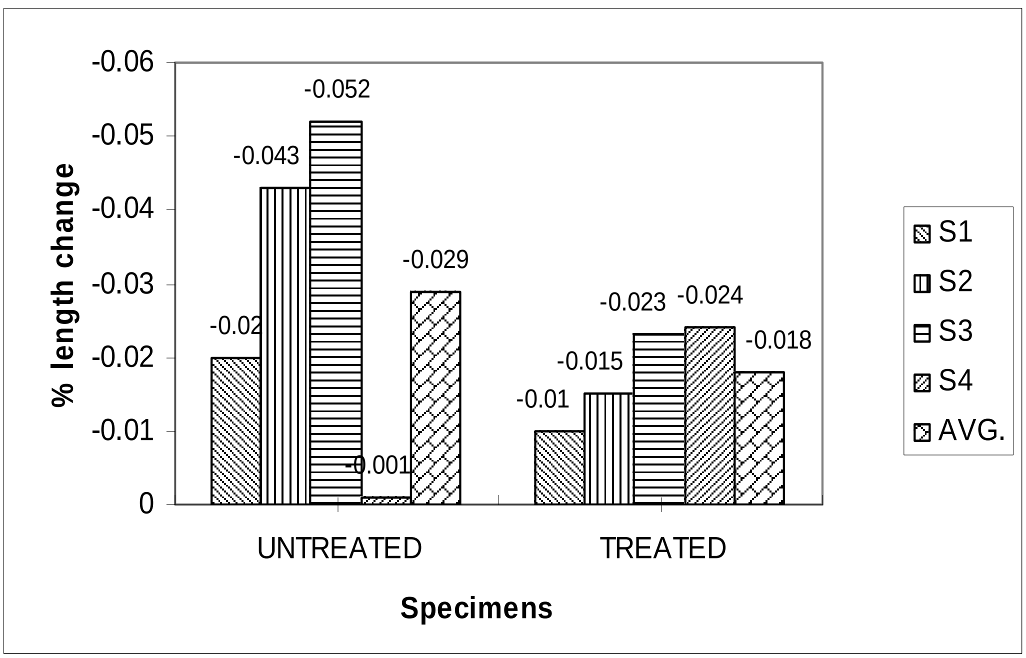

Figure 9 Percentage Length Change of Specimens for 80 Cycles

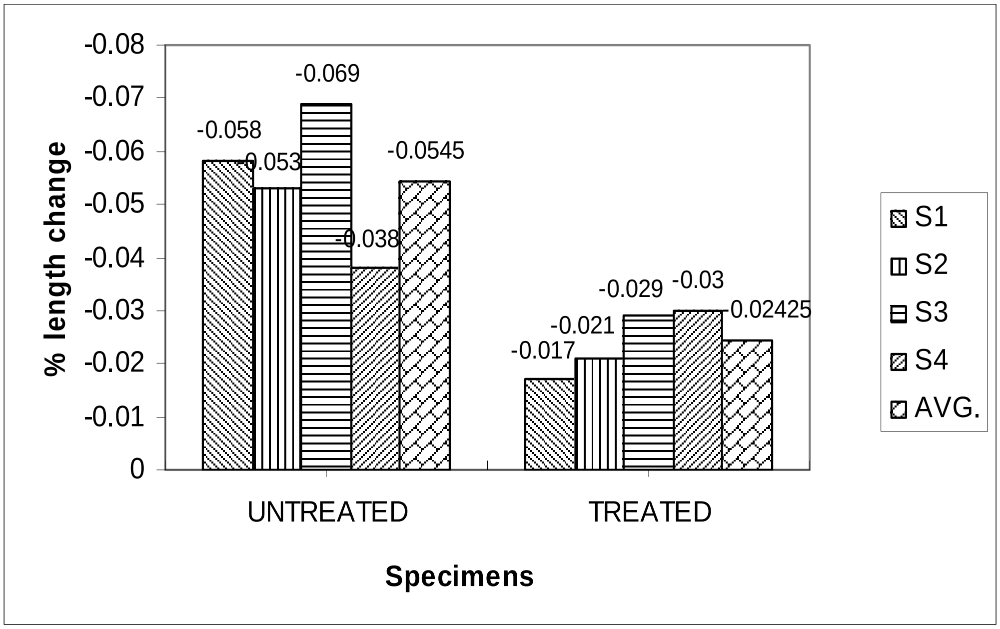

Figure 10 Percentage Length Change of Specimens for 122 Cycles

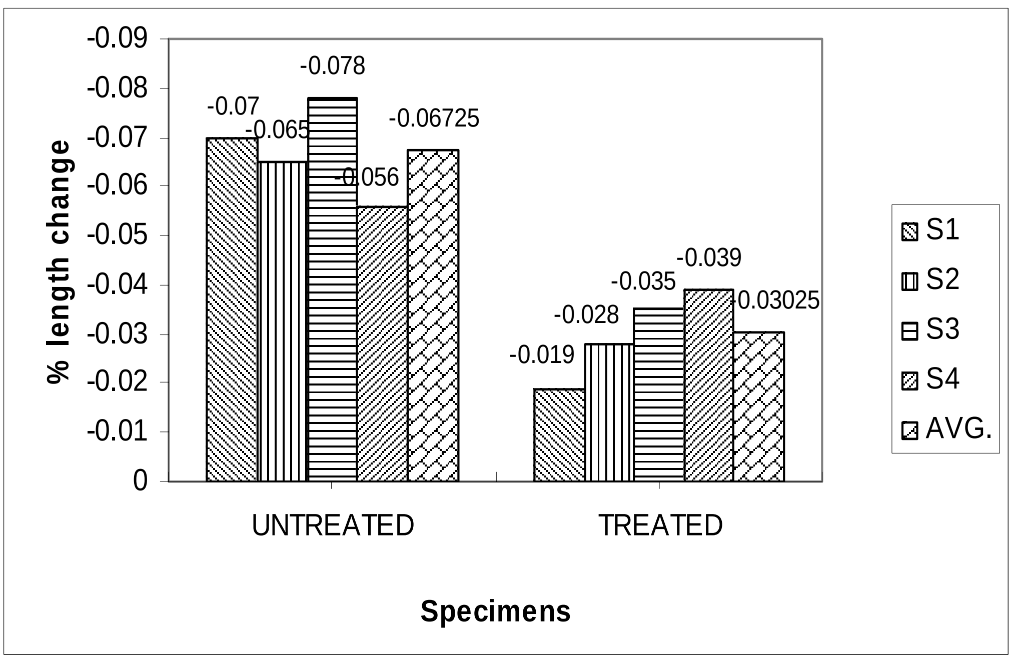

Figure 11 Percentage Length Change of Specimens for 172 Cycles

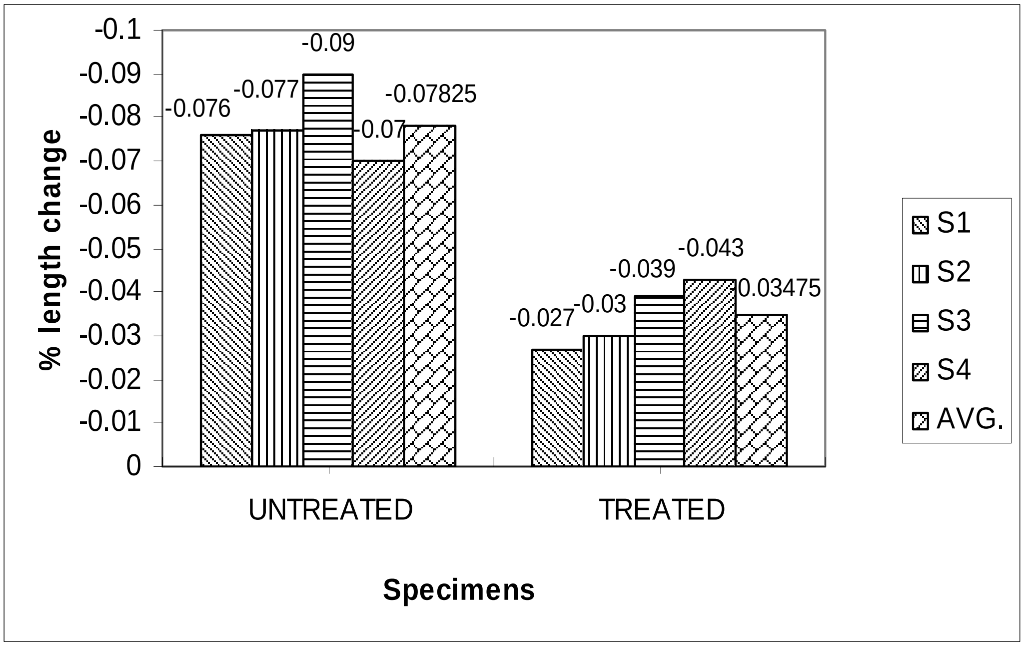

Figure 12 Percentage Length Change of Specimens for 228 Cycles

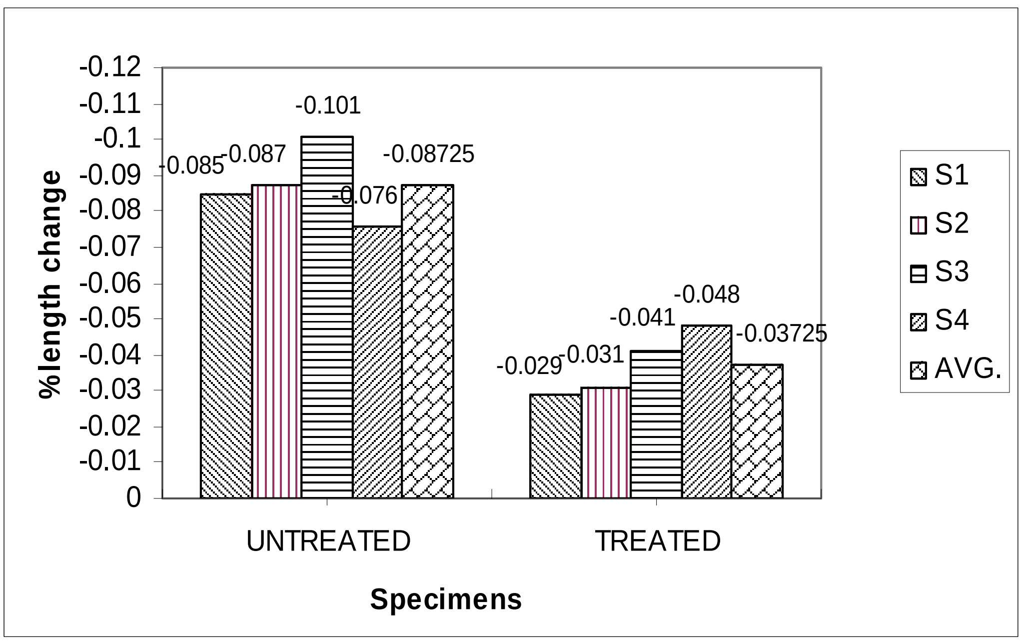

Figure 13 Percentage Length Change of Specimens for 283 Cycles

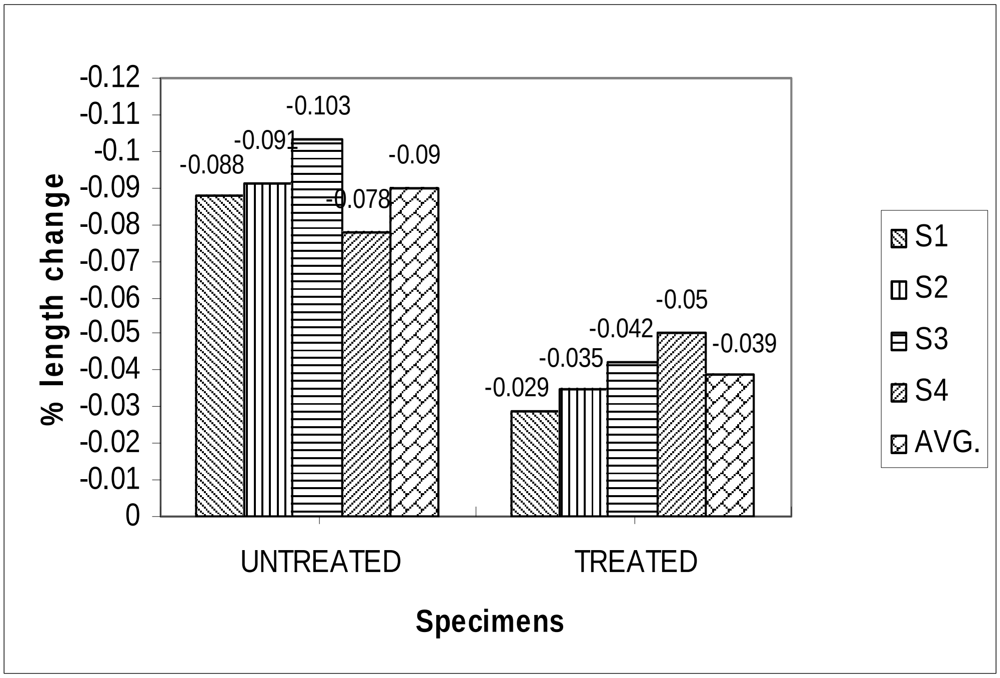

Figure 14 Percentage Length Change of Specimens for 304 Cycles

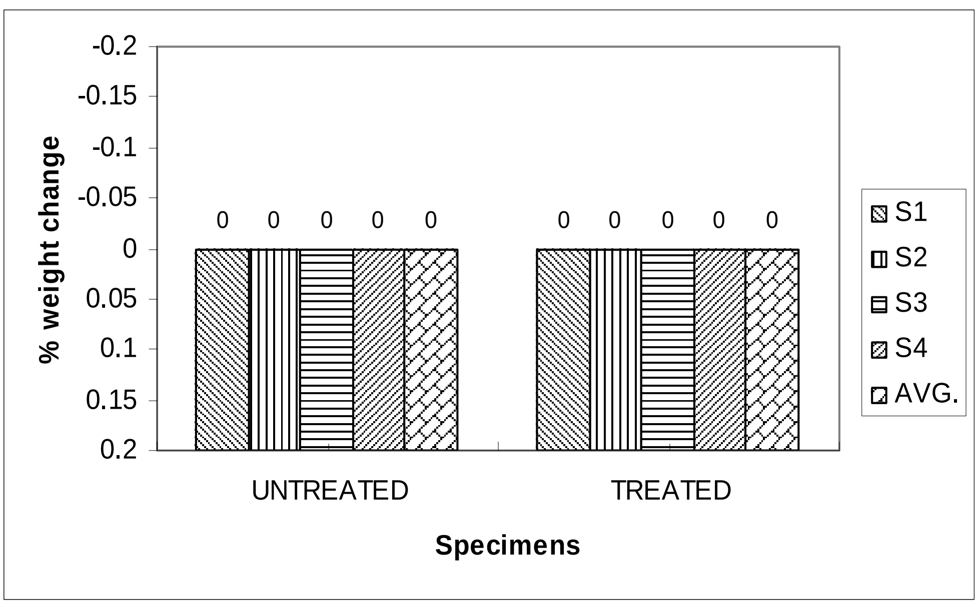

Figure 15 Percentage Weight Change of Specimens for 33 and 80 Cycles

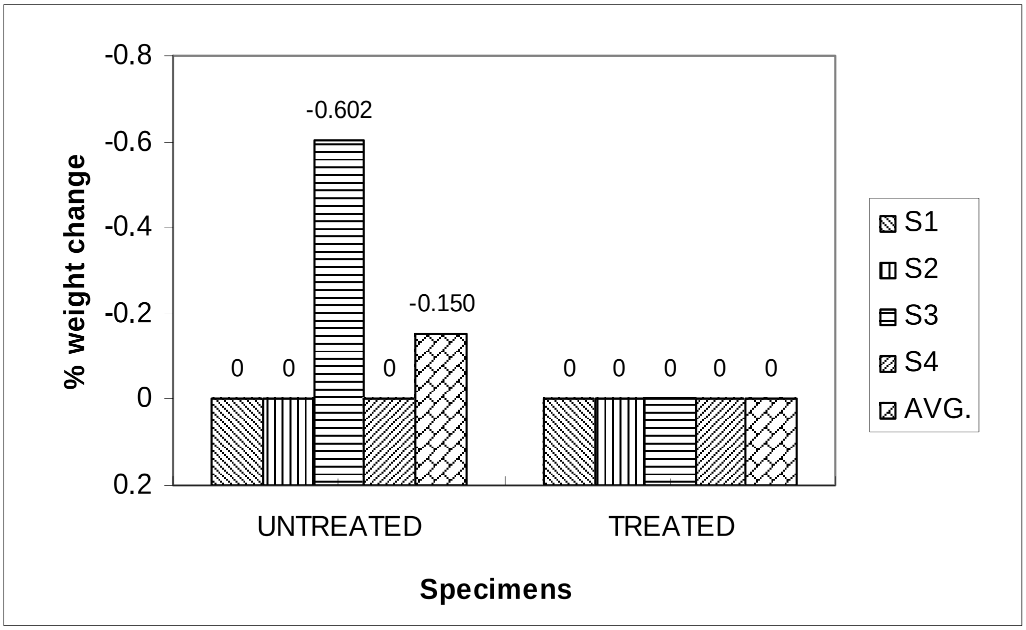

Figure 16 Percentage Weight Change of Specimens for 122 Cycles

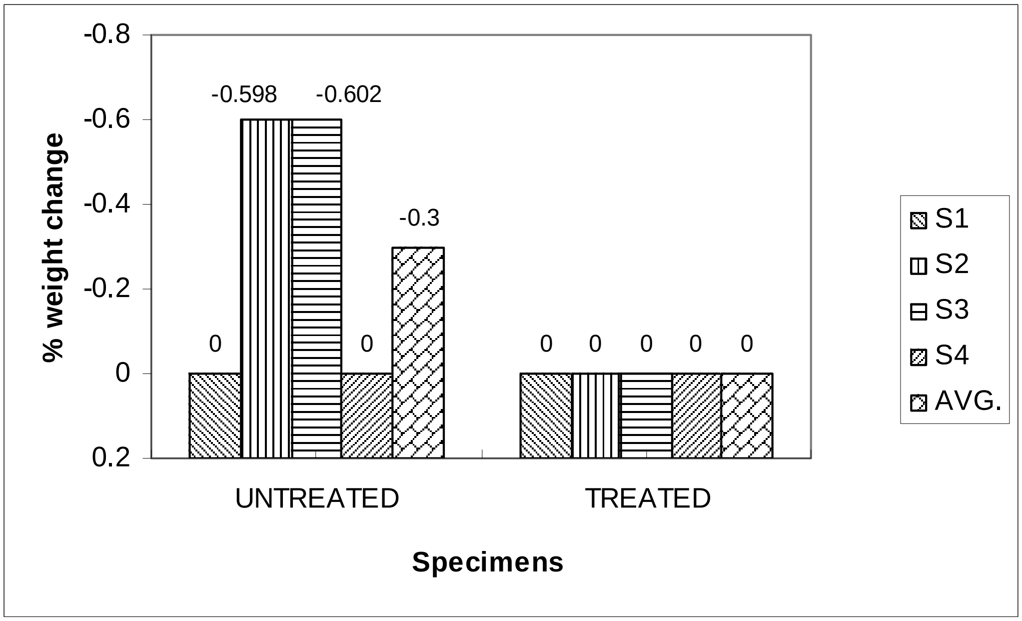

Figure 17 Percentage Weight Change of Specimens for 172 Cycles

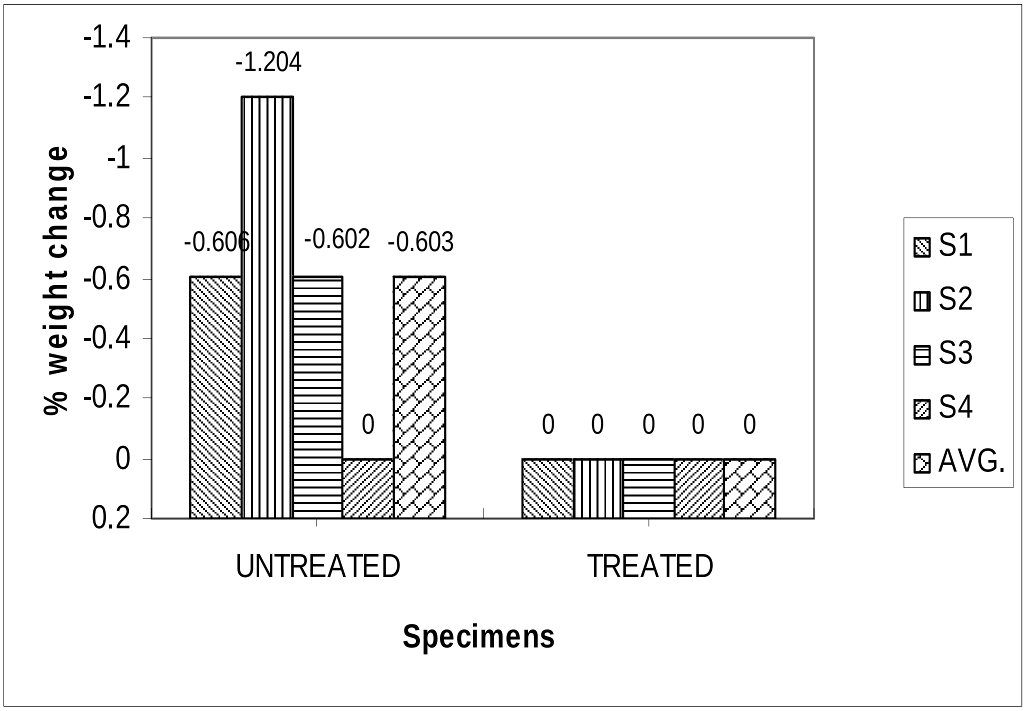

Figure 18 Percentage Weight Change of Specimens for 228Cycles

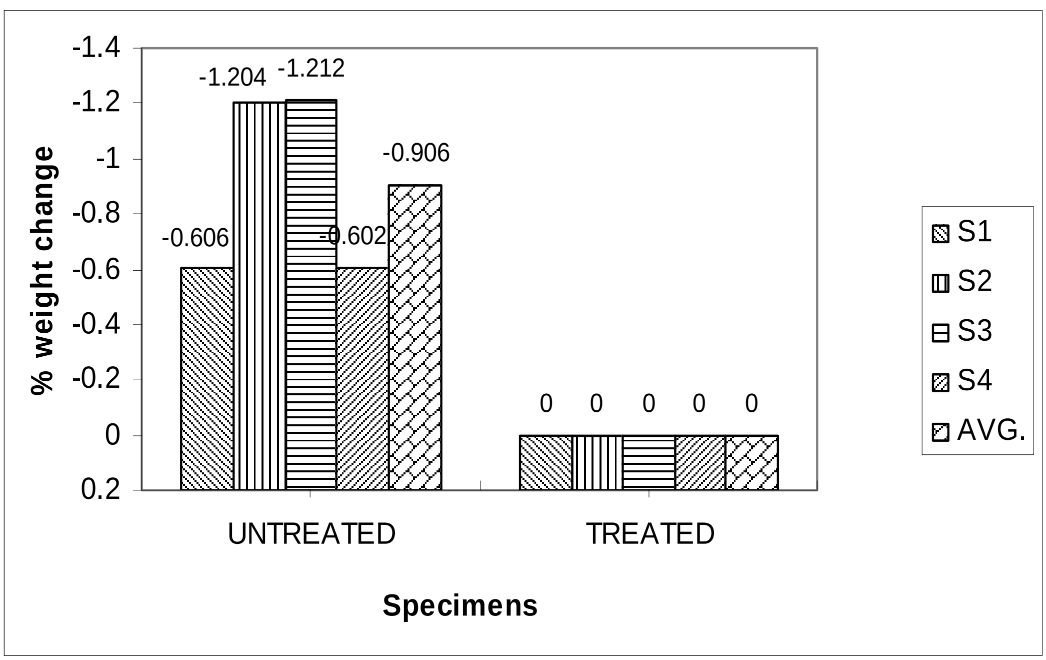

Figure 19 Percentage Weight Change of Specimens for 283 and 304 Cycles

1.6 Rapid Chloride Ion Permeability Test

The Rapid Chloride Ion Permeability standard test method is performed according to ASTM C 1202-91 and AASHTO T 277-93. The permeability test results are shown in terms of charge passing, measured in coulombs, through a two inch section of concrete specimen. The test was conducted on top two inches of concrete specimens since they were subjected to more environmental action. The age of the test specimens have significant effects on the test results, depending of the type of concrete and curing procedure. Other properties that will affect permeability test results are w/c ratio, air content and aggregate gradation.

The test specimens used for this specimens consists of both cored specimens and laboratory prepared specimens. The cores specimens both treated and untreated were provided by International Chem Crete Inc. The cored specimens were taken form parking lot and were two years old. The laboratory prepared specimens were cast in the material laboratory of UTA along with the other test specimens. The experimental test results for permeability test in cored and laboratory prepared specimens are provided in Tables 17 and 18.

Table 17 Chloride Ion Penetration Test (Core Specimens)

Sample Number	Chloride ion Permeability(coulombs)
Untreated 1	165
Untreated 2	125
Treated 1	55
Treated 2	69

Table 18 Chloride Ion Penetration Test (Laboratory Prepared Specimens)

Sample Number	Chloride ion Permeability(coulombs)
Untreated 1	4074
Untreated 2	4211
Treated 1	1790
Treated 2	2064

The test results for cored specimens show that there are negligible or very low penetrations of chloride ion for both treated and untreated specimens. This may be due to age of concrete of cored specimen since the age of the specimen has significant effects on the test results. The test result for laboratory prepared specimens show different results from that of cored specimens. The average chloride penetration of treated specimen is just below the 2000 coulombs, whereas, for untreated specimens, the chloride ion penetration is around 4000 coulombs, which is considered high. In both different kinds of specimens, chloride ion penetrations for untreated specimens are higher than treated specimens. It should be noted that specimens with average chloride penetration less than 2000 coulombs are considered durable.

The comparison between treated and untreated specimens of the cored and laboratory prepared specimens for chloride ion penetration test are presented in Figures 20 and 21, respectively.

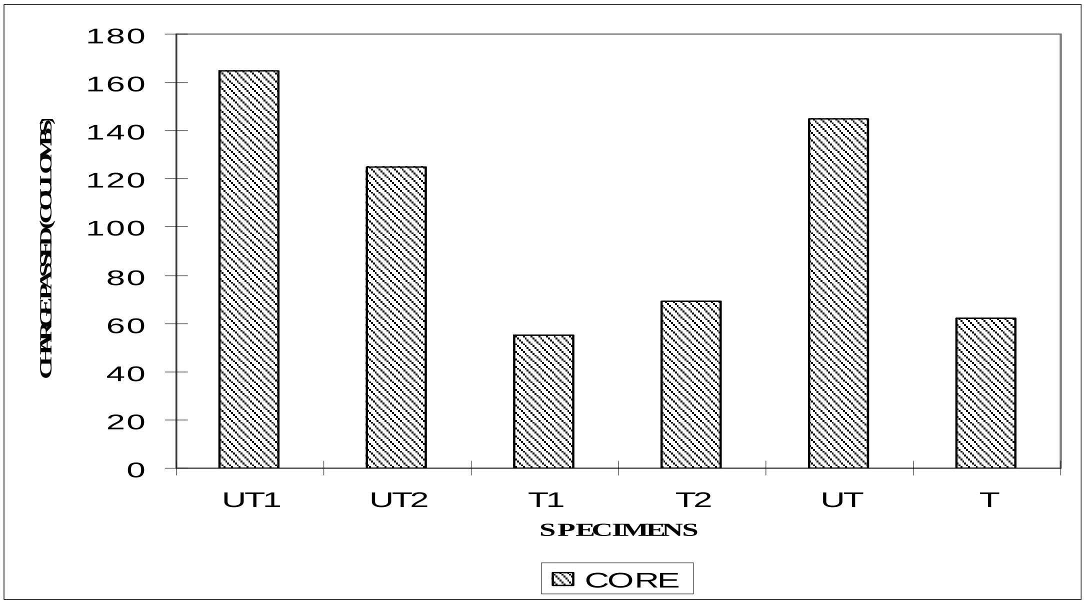

Figure 20 Permeability Test Result for Core Specimens

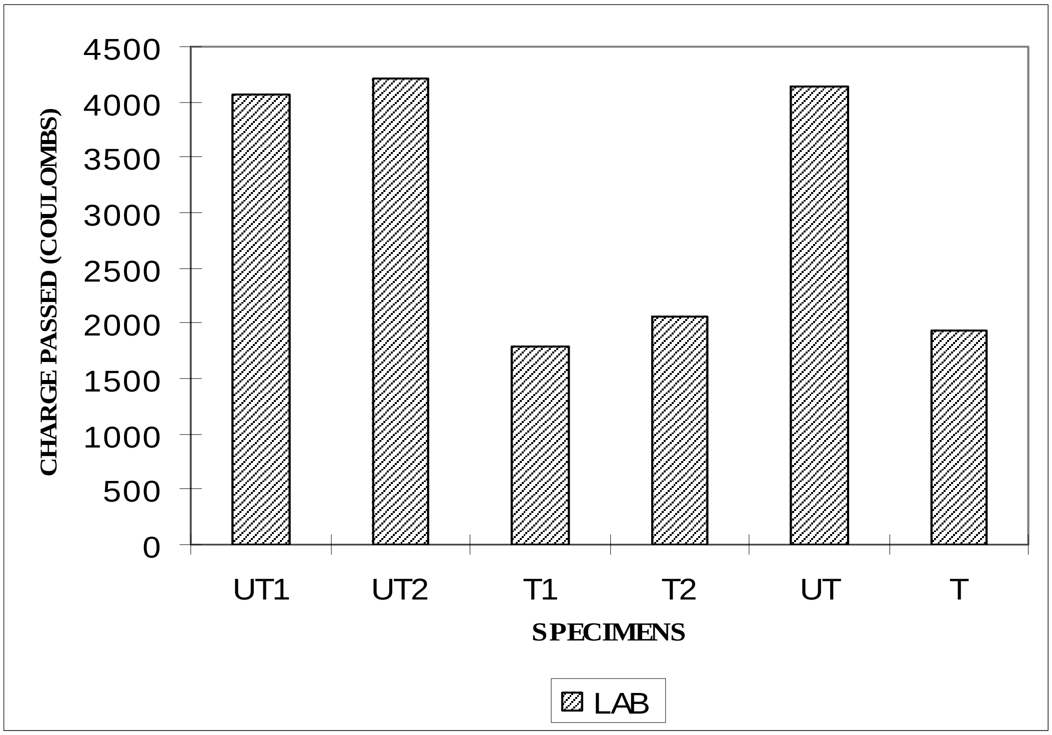

Figure 3.21 Permeability Test Result for laboratory Prepared Specimens

Figures 20 and 21 present the permeability test result of the top 2 inch layer of cored and laboratory specimens. The top 2 inch layer is important since it is in direct contact with harsh weather conditions of the environment. It can be shown from above figure; the treated specimens perform better than the untreated specimens.

1.7 Petrographic Analysis for Hardened Air Content Test

The petrographic analysis is a test to examine the repeatability of the air void structure in hardened concrete mixes. The analysis breaks down the air void content into entrained and entrapped air voids. The differences between the two air voids are their sizes. Entrained air voids are less than or equal to 0.04 in. nominal diameter and entrapped air voids are greater than 0.04 in. in diameter. The test results provide the spacing factor of air voids through the specimens, which are important in freeze-thaw testing. The spacing factor gives the average maximum distance from any point in the cement paste to the edge of the nearest void. The maximum value of the spacing factor for moderate exposure of the concrete is usually taken to be 0.008 in. The smaller the spacing factor for a test specimen, the greater potential that water will reach an air void where it can expand during freezing conditions without causing stress and failure planes in the concrete. The analysis test results should be comparable but slightly higher than the air content design for the mix. The petrographic analysis test will be more reliable than the lab measured air content. The petrographic analysis is conducted for the same specimens used for the chloride penetration test.

The experimental test results of petrographic analysis for both cored and laboratory prepared specimens are given in Tables 19 and 20, respectively.

Table 19 Petrographic Test Result of Core Specimens

	Untreated Specimen	Treated Specimen
Air Void Content (Percent)	0.67%	0.37%
Paste Content (Percent)	29%	15.90%
Specific Surface (in^2/in^3)	826	734
Spacing Factor, inches	0.0135	0.016
Magnification	100x	100x

Table B-20 Petrographic Test Result of Laboratory Prepared Specimens

	Untreated Specimen	Treated Specimen
Air Void Content (Percent)	9.67%	9.67%
Paste Content (Percent)	29%	33%
Specific Surface (in^2/in^3)	581	541
Spacing Factor, inches	0.0052	0.0062
Magnification	100x	100x

Results from the above tables show that the air-void content and the spacing factors for both treated and untreated specimens, as expected, are nearly same. The air-void content for the cored treated and untreated specimens are low, which is considered not desirable for freeze-thaw condition. The comparison between spacing factor and air void content are presented in Figures 22 and 23.

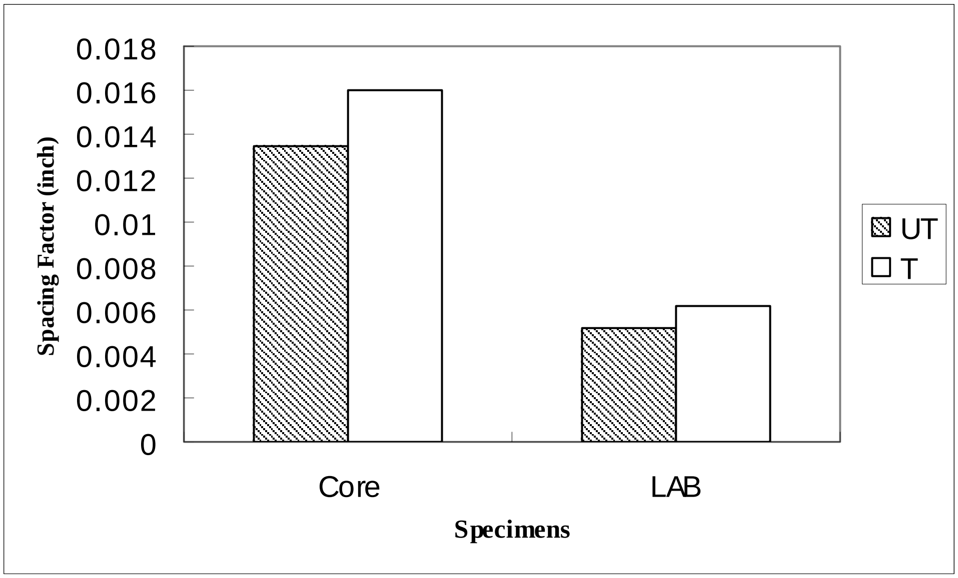

Figure 22 Comparison of Spacing Factor

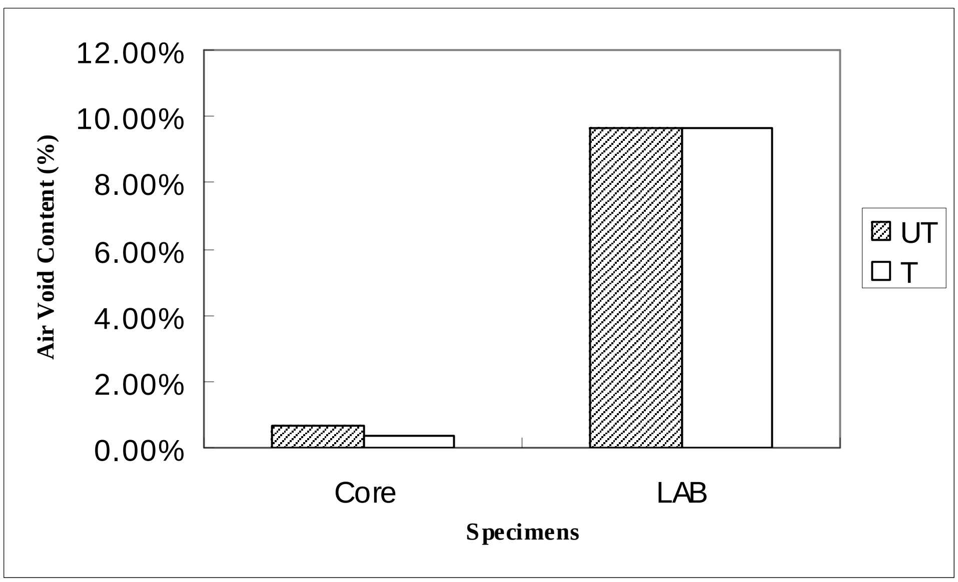

Figure 23 Comparison of Air Void Content

Figure 22 shows that the spacing factor for the treated and untreated specimens for both cored and laboratory prepared samples are nearly same, which are 0.016 in. and 0.135 in., respectively. This is considered to be not desirable for the concrete with good resistance to freeze-thaw damage. The spacing factor for laboratory prepared treated and untreated specimens are 0.0062 in. and 0.0052 in., respectively, which is considered acceptable for the concrete with good resistance to freeze-thaw damage. A smaller spacing factor is considered better for the freeze-thaw durability. It can be seen from Figure 23 that the air void content for the laboratory prepared treated and untreated specimens have the same air void content of 9.6%. This air void content of 9.6% is considered to be excellent for the concrete with good freeze and thaw resistance.

2. Summary and Conclusion

The objective of this study was to investigate the durability properties of Chem-Crete Pavix CCC 100 treated and untreated concrete specimens. This was done by carrying out experimental investigations to study and to evaluate the damage caused by water in concrete infrastructure with and without special water proofing substance Chem-Crete Pavix CCC 100. The experimental investigation includes test such as water absorption, freeze-thaw, chloride ion penetration and petrographic analysis.

Mix design included the normal mix design used in pavement construction. The mix design was done for expected slump value of 5 in., air content of 5% and water cement ratio of 0.5. Additional mix design with 0.35 water cement ratio was done for absorption test. Aggregates used in this mix were from Bridgeport pit and Ferris pit, Texas. The entire test was performed in accordance to standard test methods explain in Chapter I.

The average 28-day compressive strength of each mix design used in this project was 3890 psi. The target 28-day compressive strength was 3500 psi. Since the entire specimen tested for the compressive test has a value more than target 3500 psi, this concrete mix design was used throughout the laboratory testing of this project.

The maximum 28- day flexural strength was 585 psi (with average value of 573 psi), which satisfies the requirements of 555 psi flexural strength set by the Texas Department of Transportation (TXDOT).

One of the key durability properties evaluated in this research study was the Absorption and Air Void test. One of the main objectives of this study was to decrease the water absorption capacity of concrete to reduce the water related deterioration. The average water absorption test result of treated specimen was 2.1% while this value for untreated specimen was 6.05% for concrete with water cement ratio of 0.5. For the concrete with water cement ratio of 0.35, the absorption capacity for treated specimen was 0.89% and that for the untreated specimen was 3.98%. In both mix, the absorption capacity was reduced on average by 72%.

For the Freeze and Thaw test, optional length change test was performed. The test results show that treated specimens show better result than untreated specimen. The average percent length change for the treated specimen was 0.039 % compare to that of for the untreated specimens with percent length change of 0.09%, which means that the treated specimens improved the freeze-thaw damage by 57 %. There was 0% change in weight in the treated specimen while the change in the weight for untreated specimens at 304 cycles was 1.212%.

The chloride ion penetration test was performed on both cored and laboratory prepared specimens. The cored samples both treated and untreated were provided by International Chem Crete Inc. The test was performed on top 2 in. layer of the concrete specimens since they were subjected to more environmental action. All tests were conducted by maintaining the potential difference of 60 volts DC for 6 hours across the ends of the specimens as per ASTM C 1202-91. Test data was collected at five minutes intervals throughout the 6-hour duration of the test. The chloride ion permeability for cored treated specimen was 62 coulombs compare to untreated specimen with the value of 145 coulombs. Both of these values are considered very low according to the ASTM standard. The chloride ion permeability for lab prepared treated specimens was 1927 coulombs compare to untreated specimens with value of 4142.5 coulombs. It should be noted that specimens with average chloride penetration less than 2000 coulombs are considered low permeable [20]. The major difference between the cored and laboratory prepared specimens may be due to the age of concrete of cored specimen since it has significant effects on the test results. Overall, in both cases the treated specimens performed according to the highly low permeable standards.

For the petrographic analysis, procedure A, the linear-traverse method was performed. The test was performed on both treated and untreated cored and laboratory specimens. The data collected form this test was used to calculate the air content and various parameters of the air-void system of hardened concrete. The air-void content was 0.37% and 0.67% for cored treated and untreated specimen, respectively, which is considered to be very low for the concrete with good freeze-thaw resistance. The air-void content for both laboratory prepared treated and untreated specimens was 9.7%. The spacing factor for cored treated and untreated specimens was 0.016 in and 0.0135 in., respectively. These factor for laboratory prepared treated and untreated specimens were 0.0062 in. and 0.0052 in., respectively. These results show that the air void content and spacing factors for both cored and laboratory prepared specimens are nearly same.

In general, the test results performed based on: (1) Standard Test method for Determination of Water Absorption of Hardened Concrete Treated With a Water Repelling Coating (ASTM C 6489-99); (2) Resistance of Concrete to Rapid Freezing and Thawing (ASTM C 666-97); (3) Chloride Ion Permeability (ASTM C 1202-97, AASHTO T 277-93); (4) Microscopic Determination of Parameters in Hardened Concrete (ASTM C 457-98) on Chem-Crete Pavix CCC 100 showed that the treated concrete specimens performed superior to the untreated specimens. The conclusions of this research are as follows:

1. By applying Chem-Crete Pavix CCC 100 material on concrete the absorption ratio and permeable pore space is reduced significantly making concrete less permeable.
2. From freeze and thaw tests it was found that deterioration rate of untreated concrete is nearly double of that of treated concrete. There was no change in weight after complete 300 freeze-thaw cycles in treated specimens.
3. Chloride ion penetration test showed the similar result as in the case of other durability test in which treated specimens performed better than untreated one. Overall, it was shown that permeability is reduced significantly by application of waterproofing material.
4. The petrographic analysis was conducted to measure the actual air void content of the mix design.

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